An Evaluation of Adaptive Management and Minimal Sampling as Techniques for Optimizing Rainbow Trout Stocking Rates

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ABSTRACT

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Following a change in stocking rate of +40% Kentucky Lake and -40% on Alleyne Lake, length of age-3 rainbow trout declined by over 40mm in Kentucky Lake and increased by over 50mm in Alleyne Lake. Length at age 2 remained the same in Kentucky Lake but increased by 25mm in Alleyne Lake. Higher stocking rates were associated with higher ages at harvest but variation in stocking rate had little effect on either the length of creeled fish or CPUE. An intense fishery, which rapidly removes recruitable sized fish was suggested to be the factor that decouples CPUE and fish size from stocking rate. High variation in CPUE and length at capture among years suggests that more years of data collection and larger management perturbations will be needed if the effects of changes in management policy are to be detected.

ACKNOWLEDGEMENTS

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INTRODUCTION

The process of fisheries management rests on the managers' ability to use factors under their control to affect a fishery. A manager can intervene by altering variables like stocking rate or nutrient input, which affect the biological processes in a lake. Alternatively, the linkages between biological production and the fishery can be manipulated through regulations or marketing. In both cases, the management process involves three phases. In the assessment phase, the current state of the fishery is examined to determine if management intervention appears to be warranted. In implementation phase, the appropriate management action is chosen and implemented. In the evaluation phase, the outcome of the management action is assessed and compared to the goals set in the assessment phase. Each of these phases requires information to make decisions but information is an expensive commodity which is often in short supply.

The ideal management process relies on lake specific information because decisions are usually made on a lake specific basis. Data aquisition is especially difficult for fisheries that are spread over numerous small lakes. If the value of the fishery on each lake is small, then data collection programs have to be inexpensive and, therefore, little data is typically available on individual, small lakes.

In addition to, and especially in the absence of, data on specific fisheries, generalized principles are used to form conceptual models which are then used to make management decisions. Serious mistakes in management may result from the use of a model, such as "CPUE is proportional to stocking rate", if this model is erroneous. Such models of system behaviour are rarely validated because of the expense of data collection and an inherent faith in a familiar model.

The rainbow trout fishery in the small lakes of southern British Columbia requires a better data collection system to improve both the conceptual models and the lake specific data collection system. One improvement in data collection is to reduce the cost by collecting the minimum amount and types of data (Parkinson et al. 1988). A second improvement is to use management manipulations to test conceptual models of fisheries by "active adaptive management" (Walters 1986). Active adaptive management involves observing the effect of an abrupt, large shift in one of the major factors thought to be important in an management system. Both improvements should reduce a managers dependance on poorly tested conceptual models.

Parkinson et al. (1988) proposed a data collection system for small rainbow trout lakes which involved the collection of a minimal amount of CPUE, fish size, fish age and growth rate data from angler interviews and effort data from aerial counts. Since each of the measured values is not an unbiased estimate, but rather an index to be inserted into a time series, this system of data

collection was given the acronym SLIM, for small lakes index management. The purpose of this data collection system is to provide a means of implementing an active adaptive management system on a large number of lakes. The purpose of this paper is to evaluate the effectiveness of this system of data collection in assessing the result of a ± 40% change in stocking rate change on two lakes.

STUDY AREA

Alleyne and Kentucky Lakes are situated on the border between the interior Douglas fir and ponderosa-bunch grass biogeoclimatic zone in southern British Columbia about 40 km SE of Merrit, B.C at approximately 49° 55' N: 120° 34' W. Rainbow trout, stocked as yearlings, are the only species of fish in both lakes. Neither lake has an inlet or outlet and there is, therefore, no natural reproduction of rainbow trout in either lake. The lakes are physically and chemically similar (Table 1.). Each lake has approximately 30 campsites which are operated as part of a Provincial park. The main camping area and access road is situated on the narrow neck of land between the lakes.

Table 1. Physical and chemical characteristics of Alleyne and Kentucky Lakes.

	Alleyne Lake	Kentucky Lake
Area (ha)	54.6	43.7
Shoal Area (% <6m)	24	21
Mean Depth (m)	16.7	16.1
Maximum Depth (m)	35.7	36.6
T.D.S. (ppm)	308	232
Elevation (m)	975	985

METHODS

Information on CPUE as well as length, length at age and age composition for creeled fish were obtained from creel surveys on the Victoria Day (May) and Canada Day (July 1) weekends each year. Anglers were asked how many hours they had fished, how many fish they had killed, and, since 1988, how may fish they had released. Fork lengths were measured and scales collected from each fish. Where the head had been removed, the length between the fork of the tail and the anterior insertion of the dorsal fin was measured and

a regression was used to calculate fork length. Fish were aged from scales, length frequency plots and, starting in 1987, fluorescent grit marks. Age composition data includes all fish from both weekends of sampling.

Boats that were fishing were counted from a small plane at midday on weekends between May and September. The number of counts per year ranged from 5-18.

Information on the size and numbers of fish stocked were obtained from the Provincial hatcheries database.

Both lakes were sampled with gillnets in October 1989. Nets consisted of both experimental gangs, graded in a multiplicative series (32mm, 41mm, 51mm, 64mm, 80mm, 102mm) and gangs with mesh sizes ranging from 25mm to 89mm in 12.7 mm steps.

Boat count means and confidence limits were calculated using the square root (Y + .5) transformation recommended by Sokal and Rohlf (1981). CPUE means and standard errors were calculated using the jackknife method (Sokal and Rohlf 1981). The ratio that was used was the total catch of interviewed anglers divided by the total effort of interviewed anglers for a month (usually one weekend).

During initial sampling on the May and July holiday weekends in 1985 and 1986, fish size was judged from the comments of anglers to be adequate (generally over 300 mm) but CPUE was low (generally below .2 fish/hr) in both lakes. A decision was made to increase the stocking rate on Kentucky Lake in an attempt to increase CPUE while maintaining adequate fish size. At the same time, the stocking rate in Alleyne Lake would be lowered in an attempt to produce larger fish while maintaining CPUE at the current low level.

In the original plan, the stocking rate of both lakes was to be held constant until 1987. At this time, the stocking rate in Kentucky Lake would be increased by 40% from 560/ha to 790/ha and the stocking rate in Alleyne Lake would be decreased by 40% from 440/ha to 260/ha. Stocking rates in both lakes were 30-40% lower than requested in the spring of 1985 and Alleyne Lake was left off the stocking list and not stocked at all in 1986. Prior to 1986, the size of fish stocked also varied from year to year (Fig. 1a) but stocking rates have been held constant at planned levels since 1987. Size at stocking is important because of its effect on size at age (Fig. 1b) and, possibly, survival.

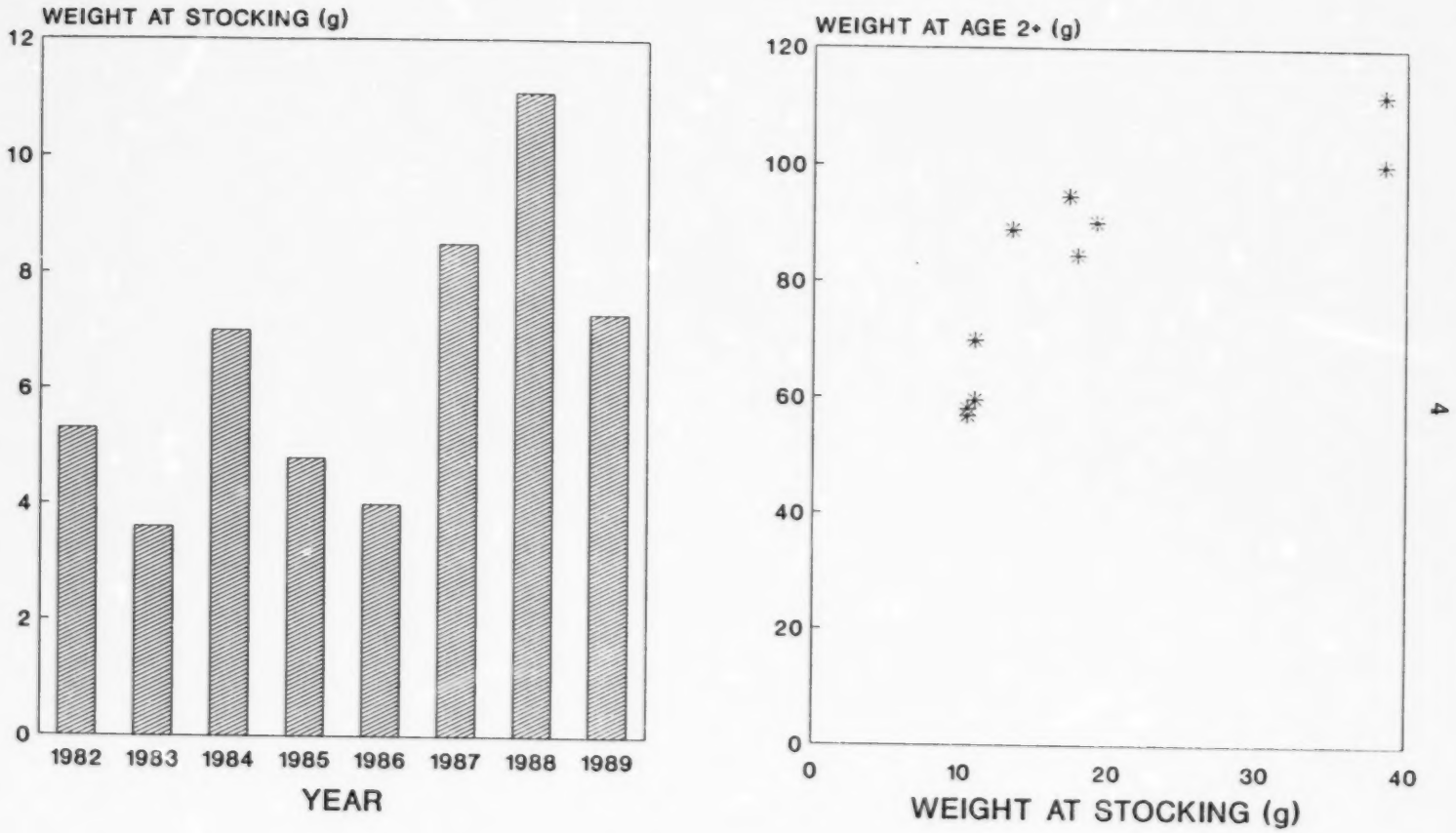

Figure 1. Time series of size at stocking in Alleyne and Kentucky Lakes (a) and the effect of size at stocking on size at age for Twin Lakes (b).

RESULTS

The goal of the SLIM system is to provide a means of, first, collecting useful data from a large number of lakes and, second, to organize the resulting large volume of data in a compact form to facilitate decision making. Accordingly, the time series for all five indices for one lake are presented on a series of 4 graphs which are printed on one page (Fig. 2 and 3). Graphs, rather than formal statistical comparisons, were used because I felt that this type of experimental management lacks the statistical rigor typical of replicated experimental design. Graphical images facilitate the interpretation of data especially as managers become familiar with a particular form of presentation. Managers should quickly develop rules of thumb (eg. 800 yearling/ha is a high stocking rate) and learn to incorporate both background knowledge and site specific information into the decision-making process for individual lakes.

In Alleyne Lake, increased growth was observed in the spring fishery in both 1988 and 1989 (Fig. 2c), presumably as a response to a lower stocking rate. A lag in the growth rate response is suggested by the lack of response in the age-2+ fish from the 1985 stocking year and the obvious response in the 1987 and 1988 stocking year classes following the absence of stocking in 1986. Despite an increase in growth rate, size at capture in 1989 was similar to 1985/86 (Fig. 2c) because of a shift to a younger age at capture (Fig. 2d). Size at capture was inflated in 1987 and deflated in 1988 because of the absence of 2+ and 3+ fish, respectively, in those years.

In Alleyne Lake, CPUE was highest in 1985, the only year in which samples are available for the original, 440/ha stocking rate. Wide confidence limits suggest that more pre-data should have been collected. CPUE was lower than expected in 1987, given the age composition of the catch in the previous 2 years and the fact that age-3+ fish were still present in the lake. Age-2+ fish recruited strongly to the fishery in 1988 and 1989 restoring CPUE to 1986 levels.

In Kentucky Lake, a decrease in growth following the increase in stocking rate was only observed in age-3+ fish in 1989 (Fig. 3c) but this response was quite dramatic. Increases in growth in 1987 and 1988 may be due to lower stocking densities in 1986 (Fig. 3a) and apparently low densities of fish in 1987 (Fig. 3b). Length at capture was similar between months within a year but there were substantial fluctuations between years (Fig.3c) as a result of shifts in age at capture (Fig. 3d). The large changes in age structure between years (Fig. 3d), did not appear to be related to variation in stocking density (Fig. 3a) and when combined with the apparent low density of fish in 1987 (Fig. 2b) suggest that survival of stocked fish in Kentucky Lake can vary substantially between years.

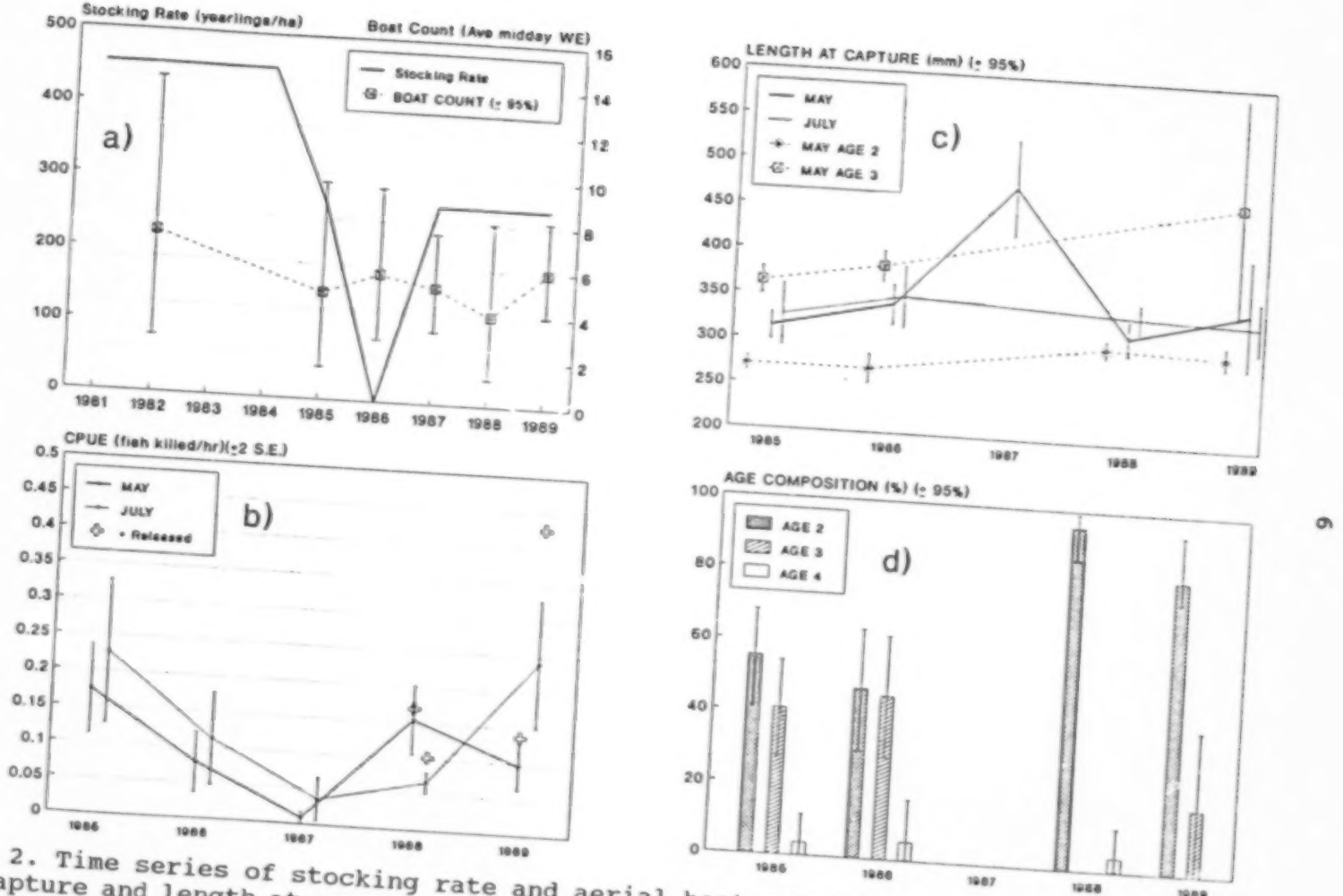

Figure 2. Time series of stocking rate and aerial boat counts (a), CPUE (b), length at capture and length at age 2+ and 3+ (c), and age composition (d) from Alleyne Lake. CPUE and biological data were collected during angler interviews on the Victoria Day and Canada Day long weekends. Age composition data is not presented for 1987 because of inadequate fish numbers.

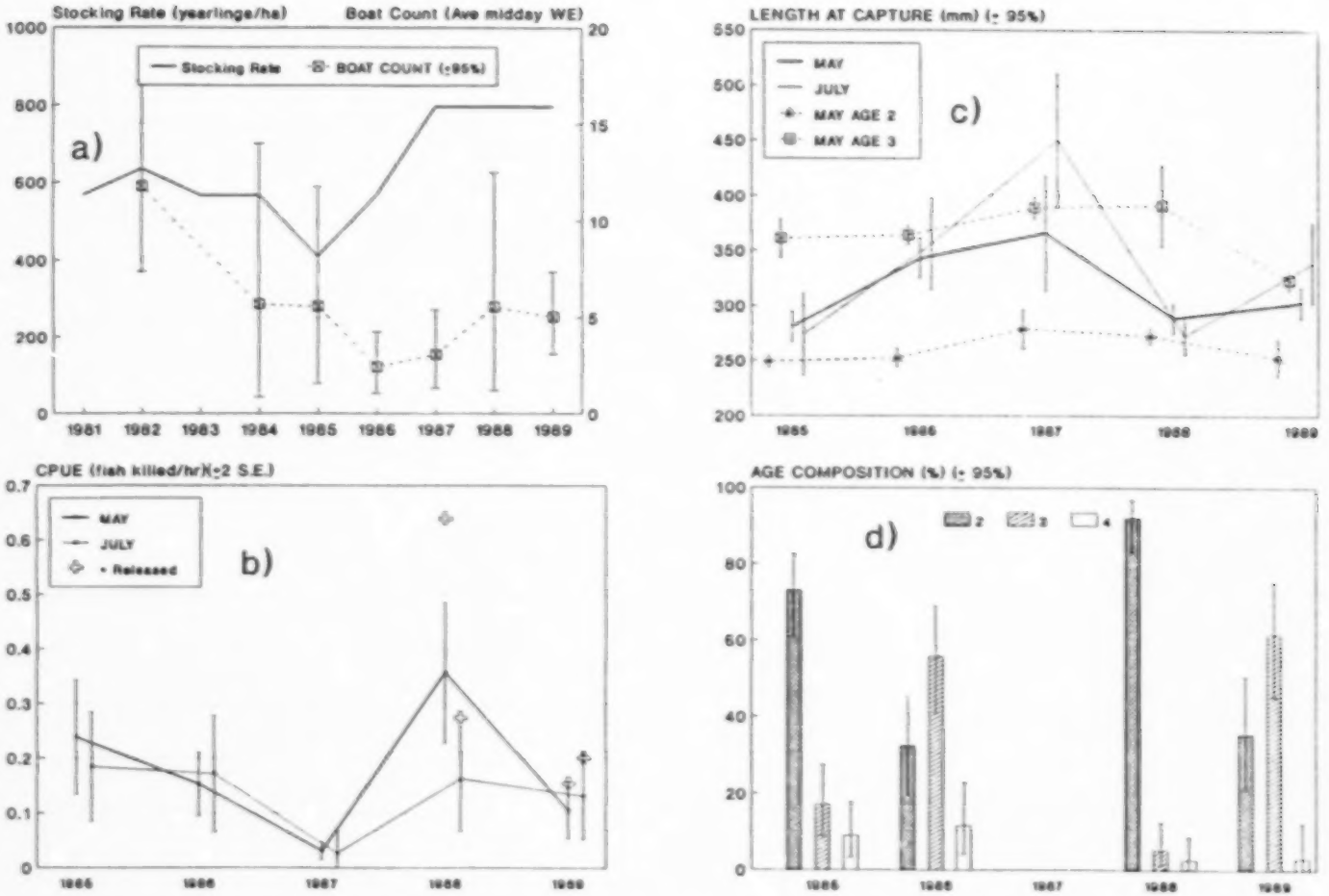

Figure 3. Time series of stocking rate and aerial boat counts (a), CPUE (b), length at capture and length at age 2+ and 3+ (c), and age composition (d) from Kentucky Lake. CPUE and biological data were collected during angler interviews on the Victoria Day and Canada Day long weekends. Age composition data is not presented for 1987 because of inadequate fish numbers.

In Kentucky Lake, high CPUE in May 1988 was at first thought to be the result of a higher stocking rate but both the 1987 and 1989 CPUE as well as the July 1988 results (Fig. 3b) suggest that CPUE is only weakly tied to stocking rate. High release rates in the fishery in May 1988 are associated with unusually high CPUE and below average fish size (Fig. 3c).

In both lakes boat counts have remained essentially unchanged through this period (Fig. 2a, Fig. 3a) but within year variation is high and a large change in effort would be needed to produce a detectable effect. Some of the variation due to season and weather can be removed by using the difference in boat count between the lakes. Although confidence intervals are somewhat smaller, relative counts on the two lakes still vary widely and there is no evidence of a shift in effort between the lakes through time (Fig. 4).

Length at age in the two types of gillnet gangs did not differ significantly and the two samples were combined. This combined sample confirms the difference in growth rate between lakes as well as the absence of older fish in Alleyne Lake in October 1989 (Fig. 5). The gillnet data also suggests that length, growth and age composition results from the 1990 spring creel survey will be similar to the 1989 values.

DISCUSSION

Active adaptive management, combined with a minimal data collection program, clarified the role of stocking in determining angling quality on these two lakes. The interpretation of these results is clouded by the lack of consistency in the stocking (size and number) and the inherent variability (within and between years) in the chosen statistics. Stocking procedures were revised in 1988 to ensure consistency and time lines will be stretched out in an attempt to deal with between year variability. An a priori power analysis (Parkinson et al. 1988) suggested that, if CPUE was directly proportional to stocking rate, the effects of the changes in stocking rate implemented on these lakes would be barely detectable with the current level of sampling. Future experiments should probably use larger perturbations. Despite these problems, the data reported here have some clear suggestions for management policy on these lakes which can be verified by future results.

Growth rate, which is generally assumed to be a function of fish density (Donald and Alger 1989) and stocking density (Donald and Anderson 1982, Lawler et al. 1974), appears to have changed with stocking rate in both Alleyne and Kentucky lakes. Length at age in the 1989 fishery increased in Alleyne Lake for both 2+ and 3+ fish and decreased in Kentucky Lake for 3+ fish. Gillnet sampling confirms that growth rates are presently higher in Alleyne

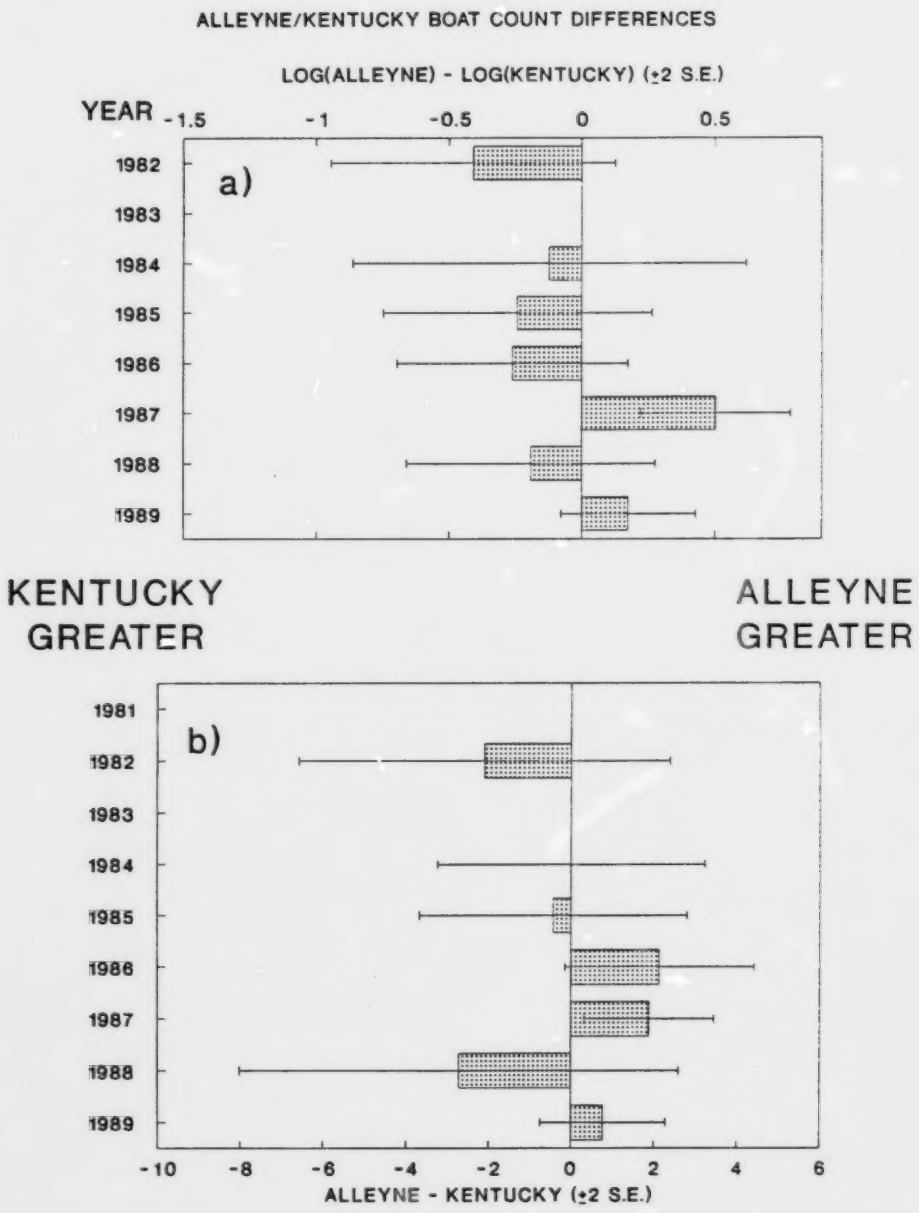

Figure 4. Differences in the natural logarithm of boat counts (a) and boat counts (b) between Alleyne and Kentucky lakes. In both cases the value for Kentucky Lake is subtracted for the value for Alleyne. Note that the difference in logarithms is equivalent to a ratio of the two counts.

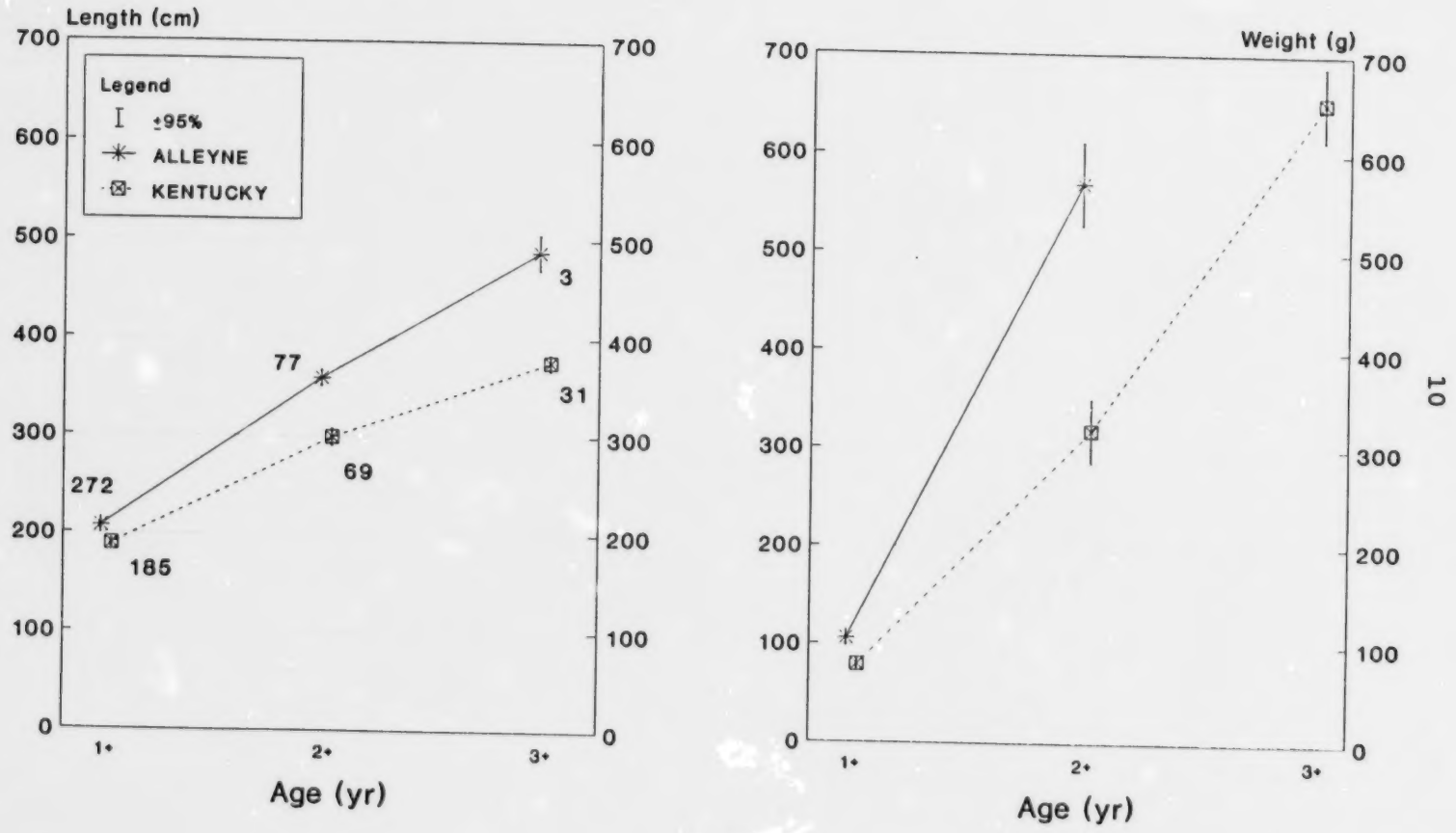

Figure 5. Length and weight at age for Alleyne and Kentucky lakes in October 1989. Numbers beside data points are sample sizes. Bars are 95% confidence limits.

Lake than in Kentucky but the 1985 and 1986 creel survey data suggests that there was a somewhat smaller difference in these years as well. Higher than normal growth rates in 1987 and 1988 in Kentucky Lake may be due the apparently low density of fish in 1987.

There are a series of problems with the index of growth rate used in this study. The length at age observed in a fishery is typically biased. Early harvest of fast growing fish can bias growth rates either upward, for a cohort just entering the fishery, or downward, for older cohorts in which faster growing fish have been in the fishery longer. Size at stocking also has to be standardized if length at age is to be a true reflection of growth rate. CPUE may also affect estimates of growth rates indirectly. When CPUE is high, there may be a tendency to release small fish and therefore inflate the measured growth rate of cohorts that are just reaching recruitable size. It should be noted that most methods of estimating growth rates have similar or related problems in their interpretation.

Large differences in growth rate have not been translated directly into large differences in the size of creeled fish. The difference in CPUE is also less than expected suggesting that two of the most important indicators of angling quality (CPUE, fish size) may not be particularly sensitive to changes in stocking rate. The hypothesized compensation mechanism involves a lower growth rate which increases the time to recruitment at higher stocking density (thus lowering survival to recruitment and, therefore, CPUE), combined with a high harvest rate of fully recruited fish. Thus, in an intense fishery, high and low stocking rates produce similar sized fish because fast growing fish are harvested at a younger age. Similar CPUE's result from different stocking rates because, at high stocking rates, fish have to survive longer to reach recruitable size and, at high harvest rates, fish are removed rapidly upon reaching a fully recruited sized.

Evidence for this hypothesis comes from the shift to younger age-at-capture in Alleyne Lake in 1989 (creel and gillnet) which suggests that the faster growth rate of age-2+ fish in 1988/89 resulted in earlier, fuller recruitment of this age class. The older age at capture in Kentucky Lake suggests that many fish are not fully recruited at age-2+ even when the length at age 2+ <u>in the fishery</u> is over 25cm. The result is that fish size at capture is not as sensitive to changes in growth rate as may be expected since slow growing fish simply tend to be left in the lake to grow to a fully recruited size. Data from Kentucky Lake, however suggests that survival can vary significantly from year to year and that additional data is needed to verify this hypothesis.

One implication of this hypothesis is that both CPUE and

average fish size in the creel can be controlled by the fishery as well as the density of fish stocked in the lake. A parallel situation exists for commercial fisheries of wild stocks where "growth overfishing" (Gulland 1980) can occur even when recruitment is adequate. In the case of intense sportfisheries supported by stocking, recruitment overfishing is obviously not a problem but growth overfishing can reduce both CPUE and fish size by harvesting the fish soon after they reach recruitable size. Obviously CPUE and fish size cannot be completely independent of stocking rate. The key factor decoupling CPUE and fish size from stocking rate is the presence of an intense fishery which removes fish rapidly after they reach a recruitable size. In this type of situation, CPUE and fish size can only be increased by reducing the harvest rate; either by controlling effort or by imposing size or quota restrictions.

As predicted by Parkinson et al. (1988), length at age is the parameter that is estimated most precisely in this sampling program and small changes in growth rate are therefore easily detectable. For length at harvest, substantial between year variation, caused shifts in age composition from year to year, implies that the number of years of data collection will have to be increased to detect differences in the order of 50mm. Examination of confidence limits suggests that the differences between years in age composition are not a result of small sample size. An estimate of the number of years of sampling required to detect differences in length at harvest is not possible because unplanned variation in stocking rates precludes the estimation of between year variation in age composition.

CPUE also varies substantially between years. Only some of this variation is associated with changes in stocking rate (eg. the decline in Alleyne Lake between 1985 and 1986) again implying that more sampling may be needed to detect CPUE changes of about $\pm$ 50%. If data on fish released by anglers is not collected, variation in CPUE may be underestimated because high CPUE is associated with a high rate of release. The key to detecting changes in CPUE in response to changes in management policy lies as much in the impact of the management policy change as it does in additional sampling. A management policy designed to double the CPUE will be detectable with minimal sampling whereas a change of 50% will not be noticeable by either the anglers or the management agency.

The absence of trends in the effort data is not surprising in light of the high variability and lack of consistent trends in both CPUE and fish size. Anglers do not seem to respond to short term (annual) variation in angling quality such as the very low CPUE in 1987. In the B.C. steelhead fishery, the effort response lagged 2-3 years behind a doubling in CPUE (Billings 1986) suggesting that anglers only respond to sustained, long-term changes in CPUE.

Implementation of adaptive management techniques provided limited insight on the effects of stocking rate changes on Alleyne and Kentucky lakes. The two key problems are: a larger than expected annual variation in critical variables, and the minimal effect of the change in stocking rate. Walters (1986) emphasizes that changes in management policy have to be large because of the large variances associated with most biological systems. In future, consistent policies and long time series will be used to ameliorate the problem of annual variation.

Both the results and conclusions reported here have to be treated with caution but the SLIM system clearly can provide both management information for individual lakes and better conceptual models for managing groups of lakes. Hilborn (1987) discusses adaptive management as a method of dealing with temporal uncertainty in a single fish stock by using probing experiments to determine the current state of the system. Similar techniques should be used to deal with the spatial uncertainty inherent in the management of numerous stocks in a series of lakes. Probing experiments on individual lakes would help to define differences and similarities between the reactions of different lakes to management manipulations. In this way, systematic manipulation could be used adjust management strategies on individual lakes as well as to develop and validate conceptual models of fisheries management on a diverse set of small lakes.

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